# Rapid Refresh and High-Resolution Rapid Refresh with Smoke (RAP/HRRR-Smoke experimental forecast models)

Ravan Ahmadov[1,2] (*ravan.ahmadov@noaa.gov*)

<u>Acknowledgement</u>: E. James[1,2], G. Grell[2], C. Alexander[2], S.Benjamin[2], B.Jamison[1,2], M. Pagowski[1,2], J. Hamilton[1,2], S. Albers[7,2], J. Stewart[7,2], S. Freitas[3], G. Pereira[4], I. Csiszar[5], M. Tsidulko[8], W.Straka[6], B. Pierce[6], S. McKeen[1,2], S.Kondragunta[5], A. Edman[9], M. Goldberg[10], B. Sjoberg[10]

***JPSS proving ground and risk reduction program***

**Western Region office, NWS**

[1] Cooperative Institute for Research in Environmental Sciences, University of Colorado at Boulder, Boulder, CO, USA

[2] Earth System Research Laboratory, NOAA, Boulder, CO, USA

[3] NASA Goddard Space Flight Center & USRA/GESTAR, Greenbelt, MD, USA

[4] Federal University of São João del-Rei, MG, Brazil

[5] Center for Satellite Applications and Research, NOAA/NESDIS, College Park, MD, USA,

[6] Advanced Satellite Products Branch, Center for Satellite Applications and Research, NOAA/NESDIS, Madison, WI, USA

[7] Cooperative Institute for Research in the Atmosphere, MD, USA

[8] I.M. Systems Group, Inc, Rockville, MD, USA

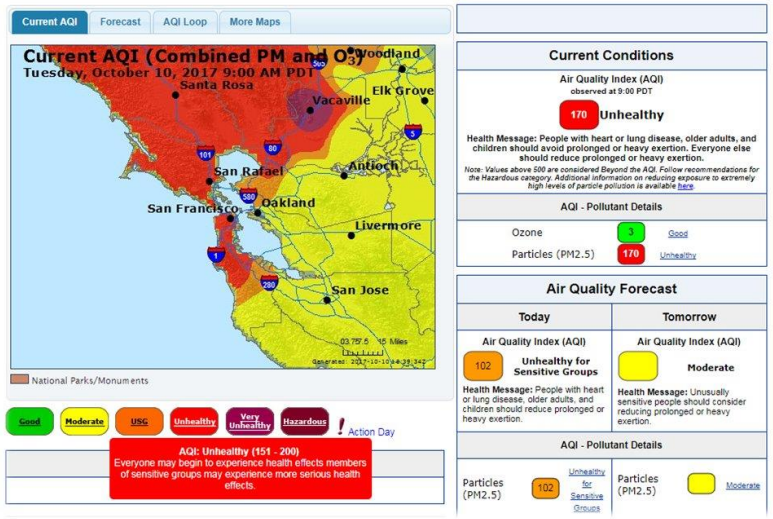
[9] National Weather Service, NOAA, USA

[10] NOAA's Joint Polar Satellite System Program Office

STAR JPSS annual conference
August 28, 2018

Smoke from wine country fires leads to 200 canceled flights, hazardous air quality.


Smoke and haze from wildfires hovers over the skyline Thursday, Oct. 12, 2017, in San Francisco. Gusting winds and dry air forecast for Thursday could drive the next wave of devastating wildfires. (Eric Risberg / Associated Press)




**There is a high demand for high-resolution smoke forecasts over the US for different applications:**

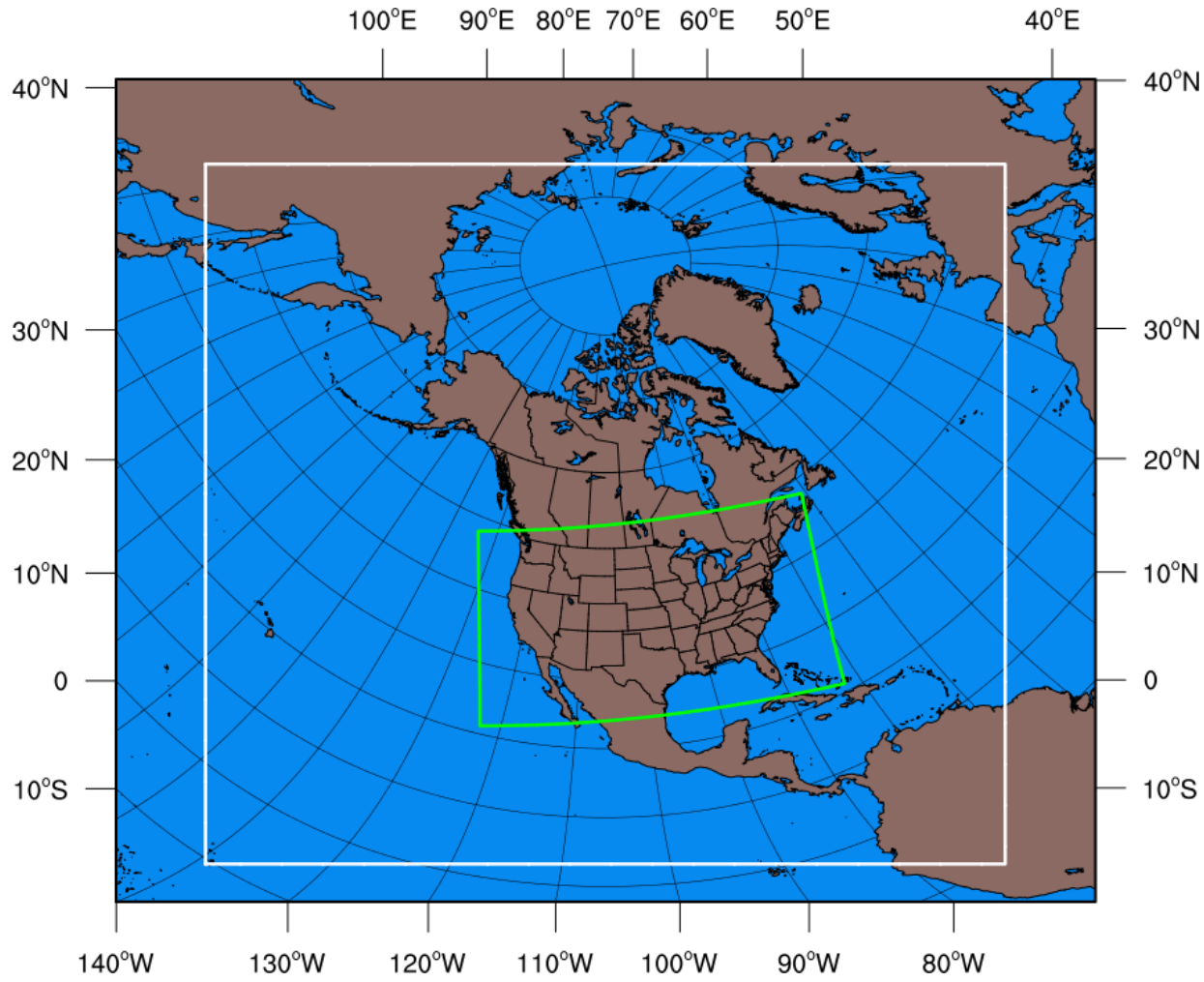
- **Air quality forecasting**
- **Visibility (transportation, aviation…)**
- **Smoke impact on meteorology to improve weather forecasting**

*Fatal accident caused by a fire smoke Interstate 40 in Arizona, October, 2016*

# HRRR-Smoke model

The main strengths of the HRRR-Smoke modeling system:

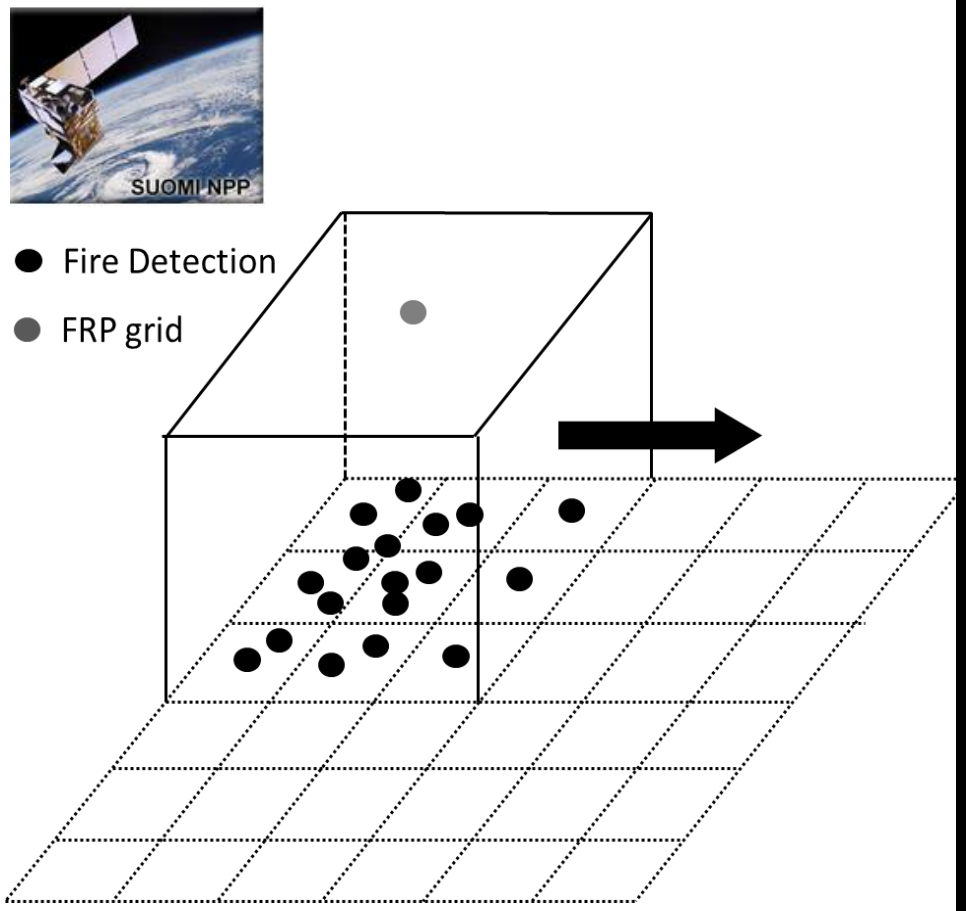
- First, we take advantage of the existing NWP systems by adding a **single tracer (smoke)** to GSD's HRRR model.
- It is a 3D model running on high spatial resolution (3km) to allow simulation of mesoscale flows and smoke dispersion over complex terrain.
- Full coupling between meteorology and smoke: feedback of smoke on predicted radiation, cloudiness, and precipitation.
- Biomass burning emissions and inline plume rise parameterization based on the satellite FRP data.
- A rapidly updating data assimilation cycle for meteorology;
- HRRR-Smoke uses meteorological input data prepared by the GSI data assimilation system and boundary conditions from Rapid Refresh (RAP).
- *Currently* the forecast lead time is 36 hours. Four times a day (00, 06, 12 and 18UTC) a new forecast starts. We plan to simulate smoke within HRRRX with hourly refresh cycle.



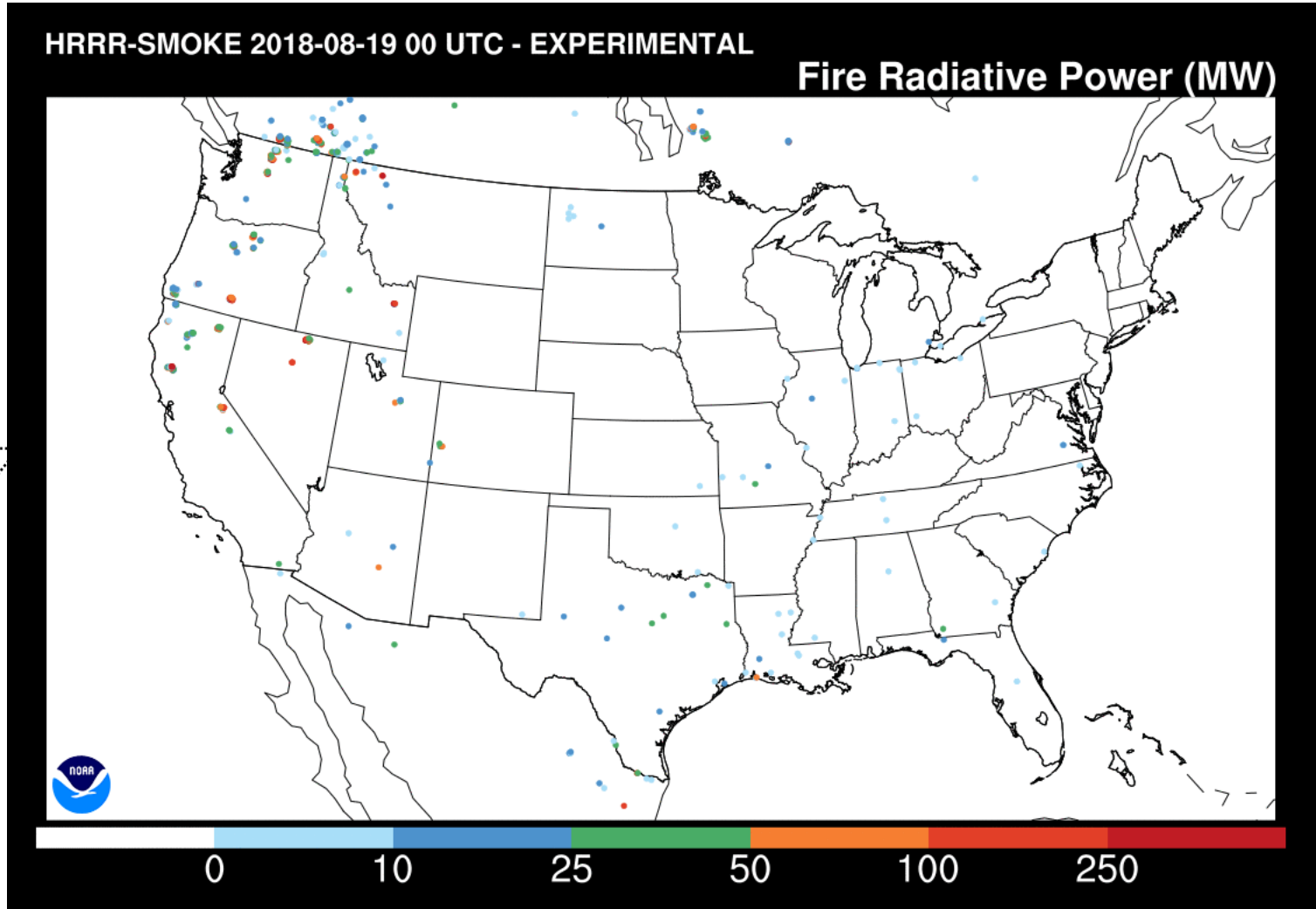

Operational weather forecast models at NWS:
RAP (white), 13km resolution
HRRR model domains (green), **3km** resolution
(https://rapidrefresh.noaa.gov/)

# Mapping the VIIRS and MODIS FRP data to the HRRR-Smoke CONUS grid

The clustering procedure performs a combination of all detected fires from VIIRS and MODIS according to the model spatial resolution and grid configuration.

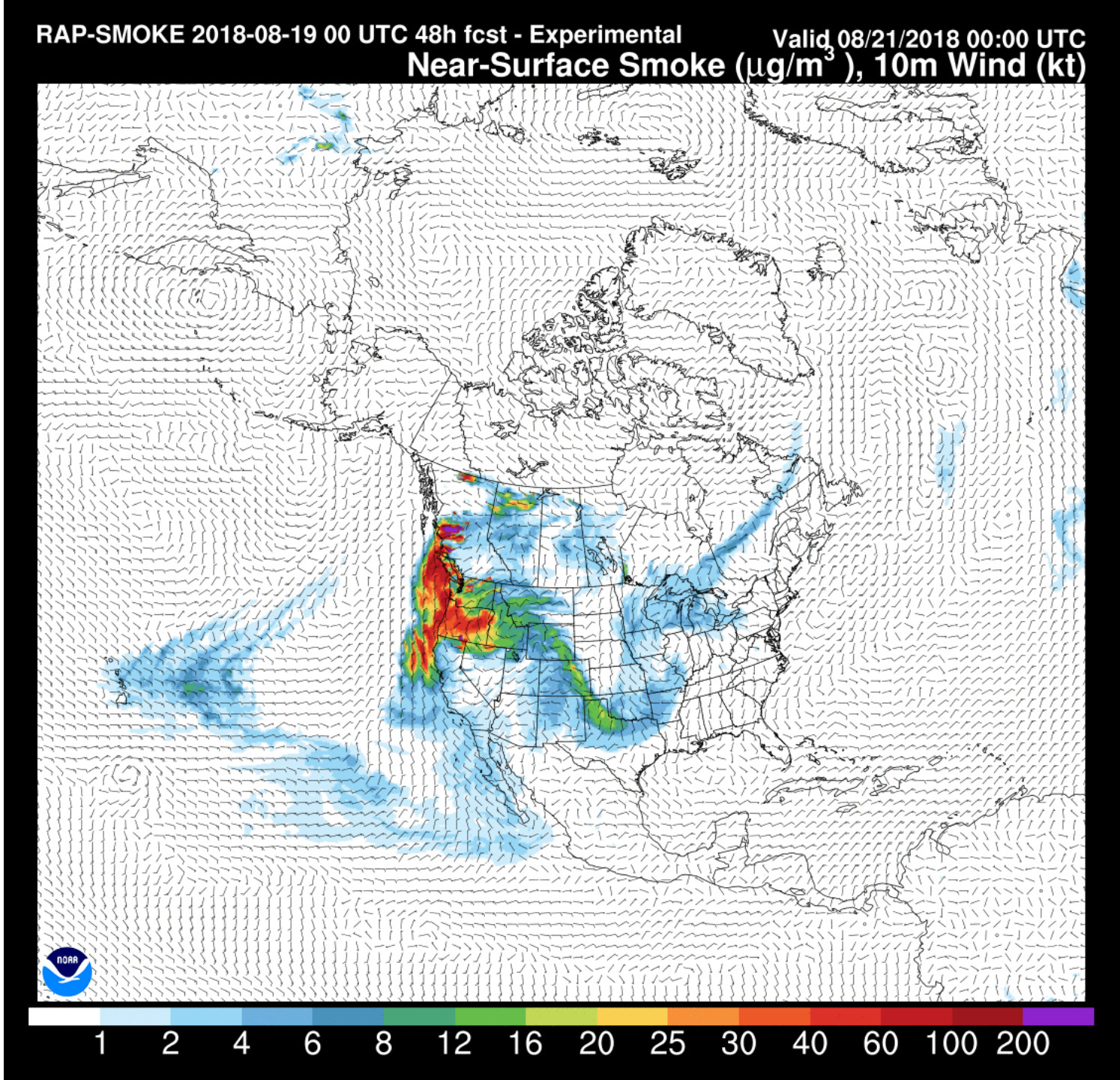



Averaged satellite FRP data mapped over 3x3km HRRR CONUS grid pixels for August 19, 2018



# Experimental RAP-Smoke (13.5 km resolution) model development

- Covers the entire North America
- Taking advantage of the global satellite data from VIIRS and MODIS
- Feeds boundary conditions for smoke to the HRRR-Smoke over the CONUS domain
- Enables capturing smoke transport from Canada and Mexico to the CONUS domain
- Forecast lead time is **48** hours. A new forecast starts every 6 hours.
- The experimental smoke forecast products are displayed: https://rapidrefresh.noaa.gov/RAPsmoke/



# The real-time HRRR-Smoke web-site for public access (rapidrefresh.noaa.gov/hrrr/HRRRsmoke/)

**HRRR-Smoke Model Fields - Experimental**

**Model: HRRR-smoke (Experimental) Area: Full Date: 19 Aug 2018 - 00Z**

*** Experimental forecast, use at your own risk *** - Quick Guide RAP-Smoke (North America domain, 13.5 km resolution)

Visualization on Interactive Map

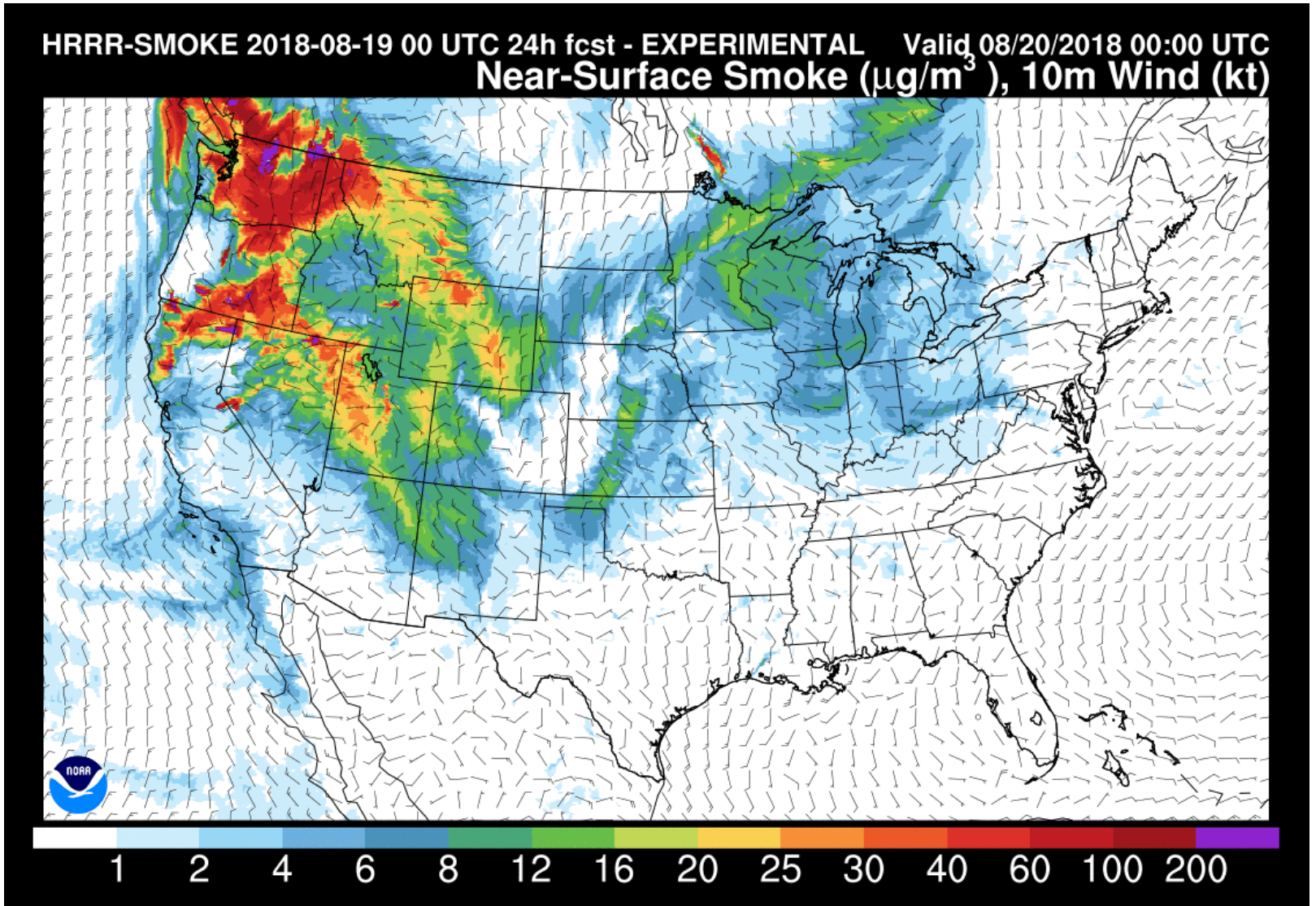
VIIRS Active fire quick guide

Model: HRRR-smoke (Experimental) Domain: Full Date: 19 Aug 2018 - 00Z

| | | | Valid Time | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sun 00 | Sun 01 | Sun 02 | Sun 03 | Sun 04 | Sun 05 | Sun 06 | Sun 07 | Sun 08 | Sun 09 | Sun 10 | Sun 11 | Sun 12 | Sun 13 | Sun 14 | Sun 15 | Sun 16 | Sun 17 | Sun 18 | Sun 19 | Sun 20 | Sun 21 | Sun 22 | Sun 23 | Mon 00 | Mon 01 | Mon 02 | Mon 03 | Mon 04 | Mon 05 | Mon 06 | Mon 07 | Mon 08 | Mon 09 | Mon 10 | Mon 11 | Mon 12 |
| | All times | Loop | Forecast | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| all fields | | | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| fire radiative power | ✓ | ✓ | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| near-surface smoke | ✓ | ✓ | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| 1000 ft AGL smoke | ✓ | ✓ | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| 6000 ft AGL smoke | ✓ | ✓ | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| vertically integrated smoke | ✓ | ✓ | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| 10m wind | ✓ | ✓ | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| 1h precip | ✓ | ✓ | | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| 2m temperature | ✓ | ✓ | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| surface visibility | ✓ | ✓ | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | |
| cross section WE CAN SN1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

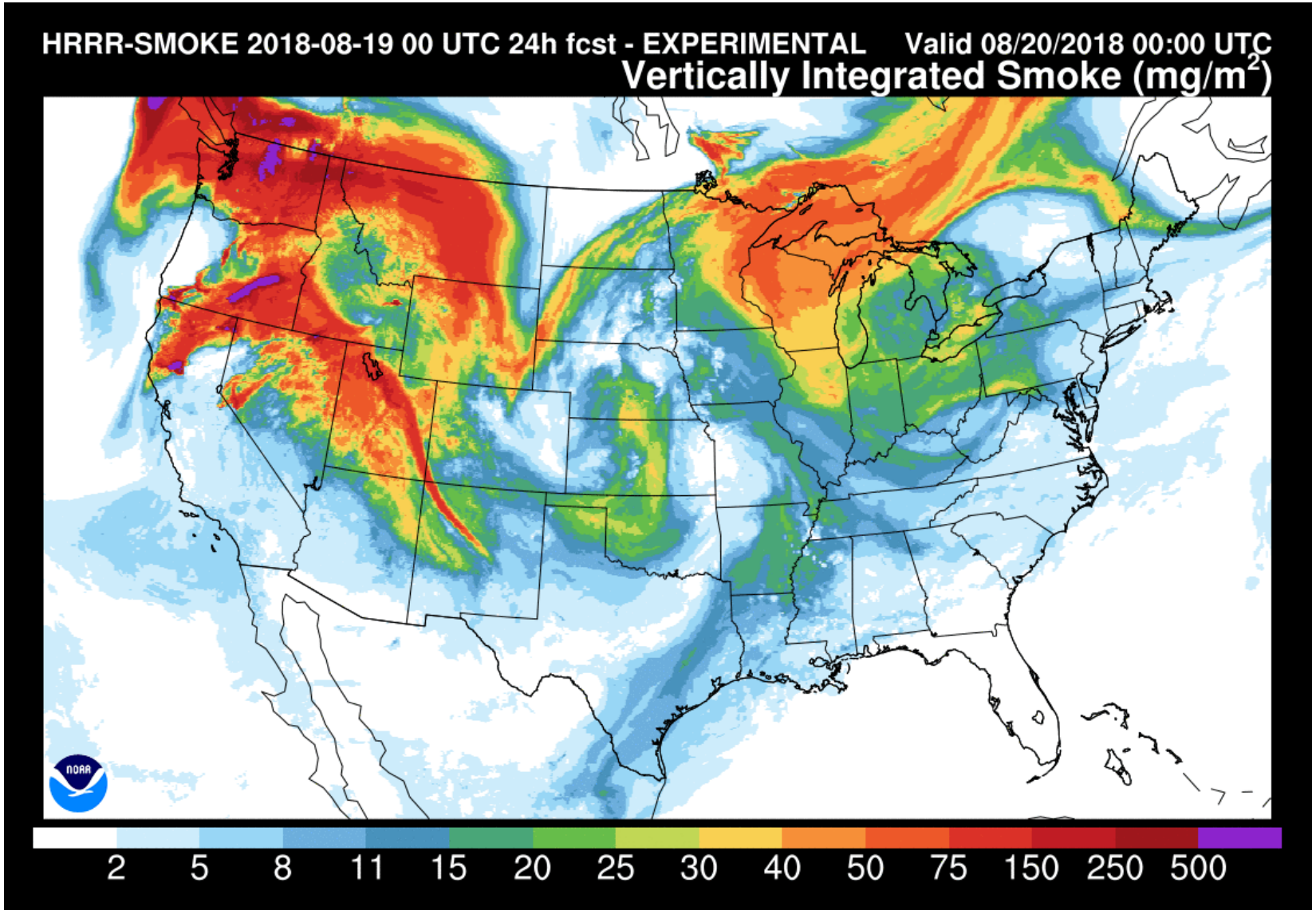
# Experimental smoke forecast for August 19, 2018 (rapidrefresh.noaa.gov/hrrr/HRRRsmoke/)

This plot shows simulated fine particulate matter (PM2.5 or fire smoke) concentrations and wind at the first model level (~8m above ground). This is the experimental forecast of the near-surface fire smoke for August 19, 6pm EDT over the CONUS. This forecast is based on the model simulation of 24 hours from the model initialization time, which is 6pm EDT, August 18, 2018.

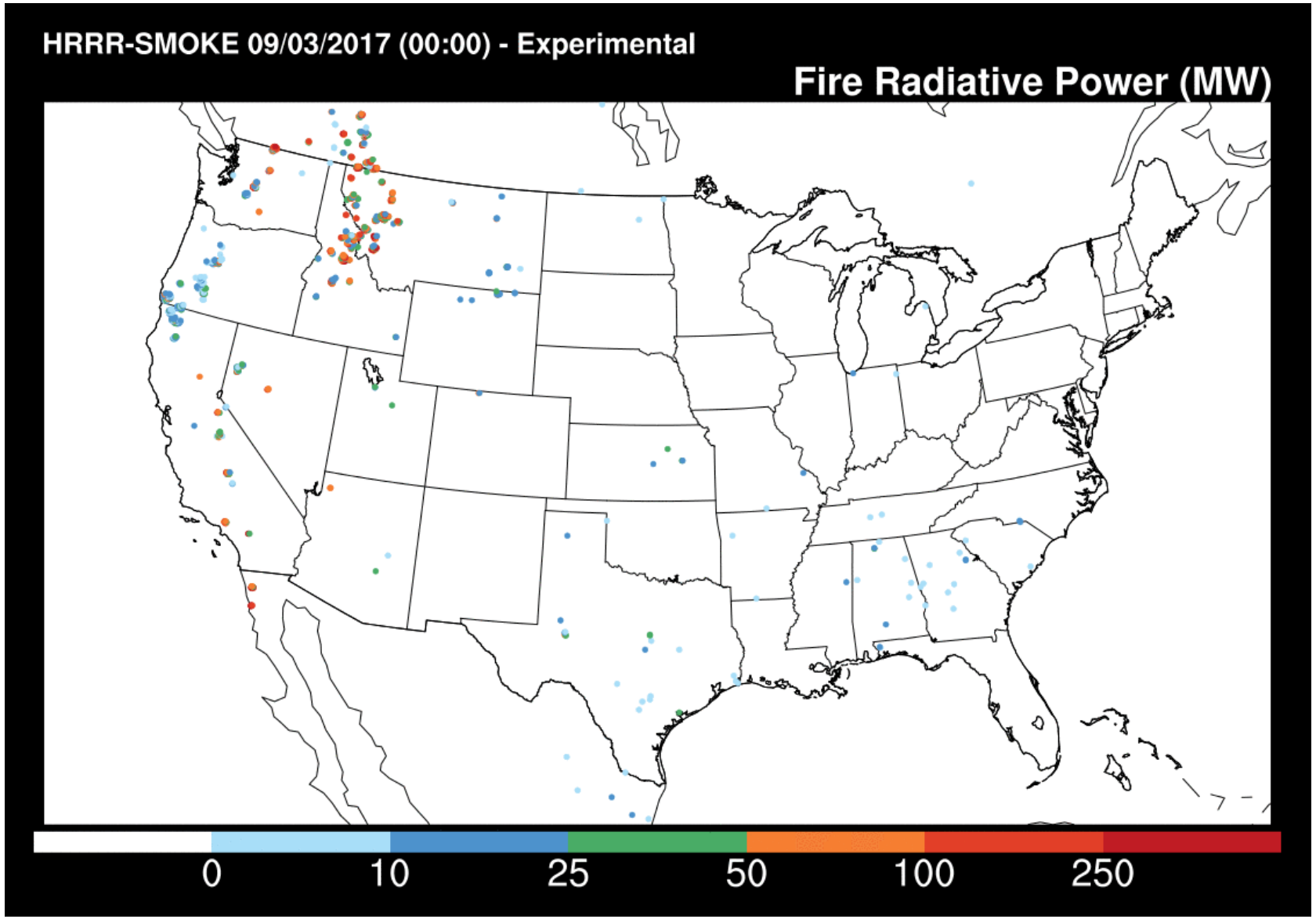


# Experimental smoke forecast for August 19, 2018 (rapidrefresh.noaa.gov/hrrr/HRRRsmoke/)

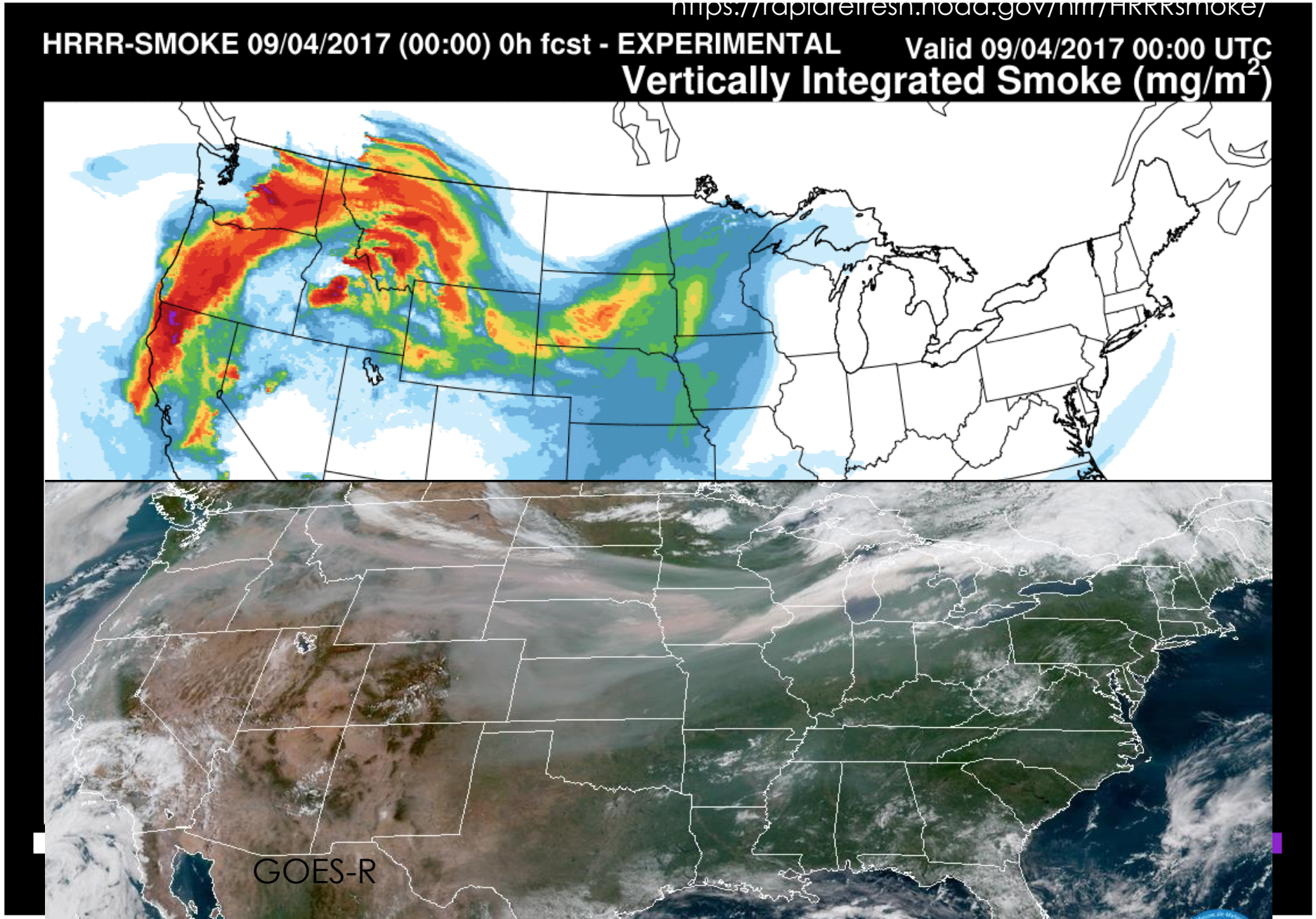
This plot shows simulated vertically integrated fire emitted fine particulate matter (PM2.5 or fire smoke) concentrations for the same forecast date/time as in previous slide.



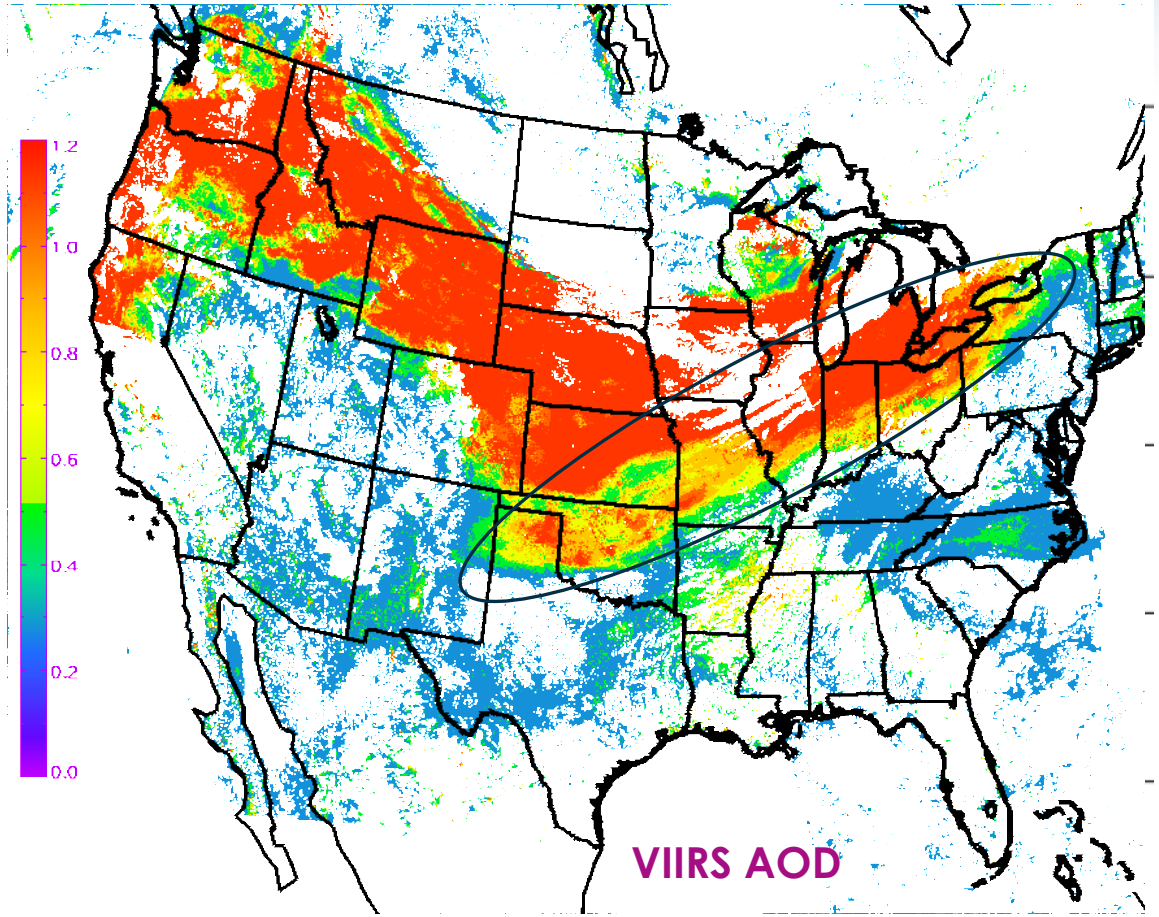
# Numerous wildfires in the northwestern US last summer

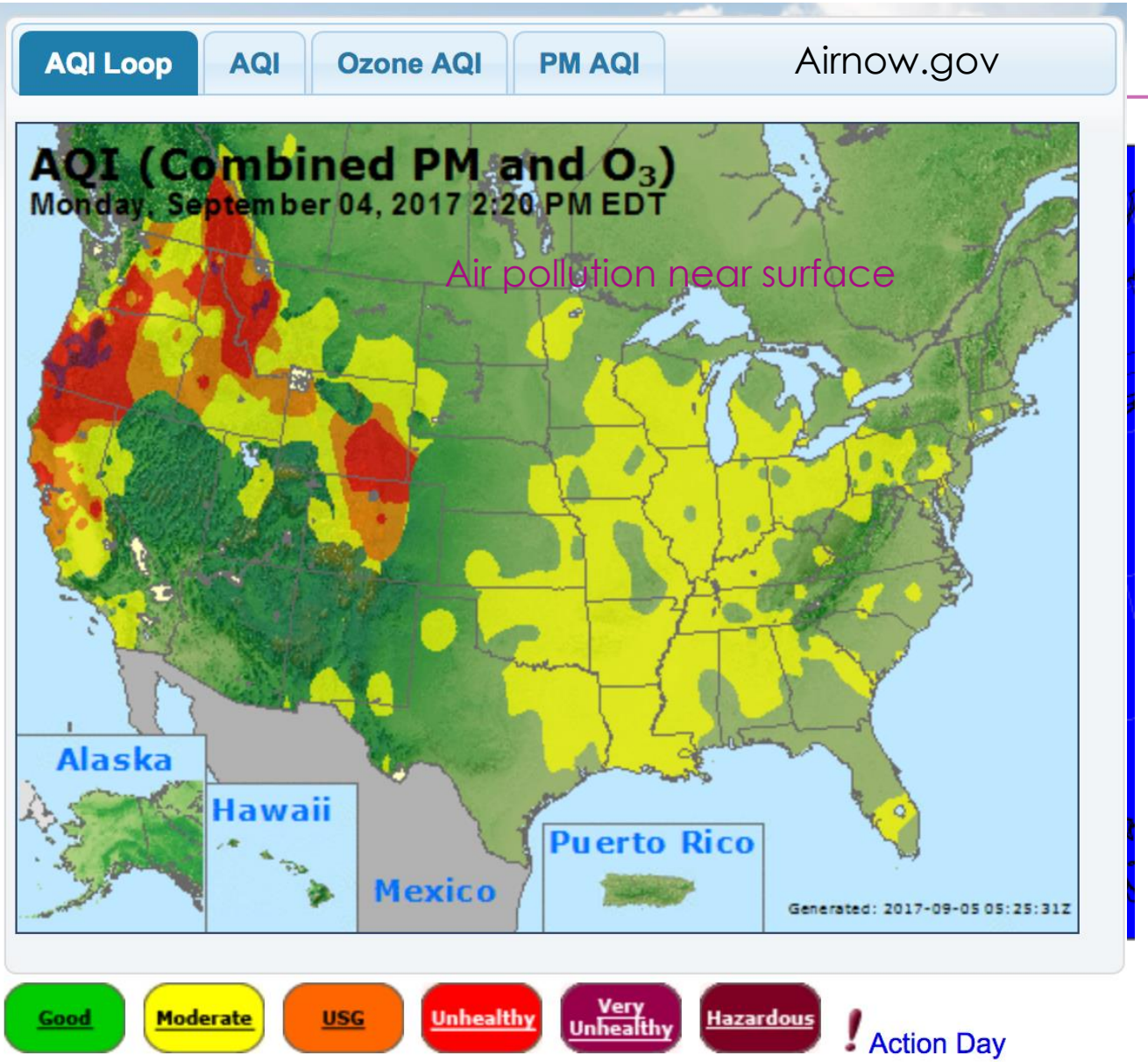


https://rapidrefresh.noaa.gov/hrrr/HRRRsmoke/



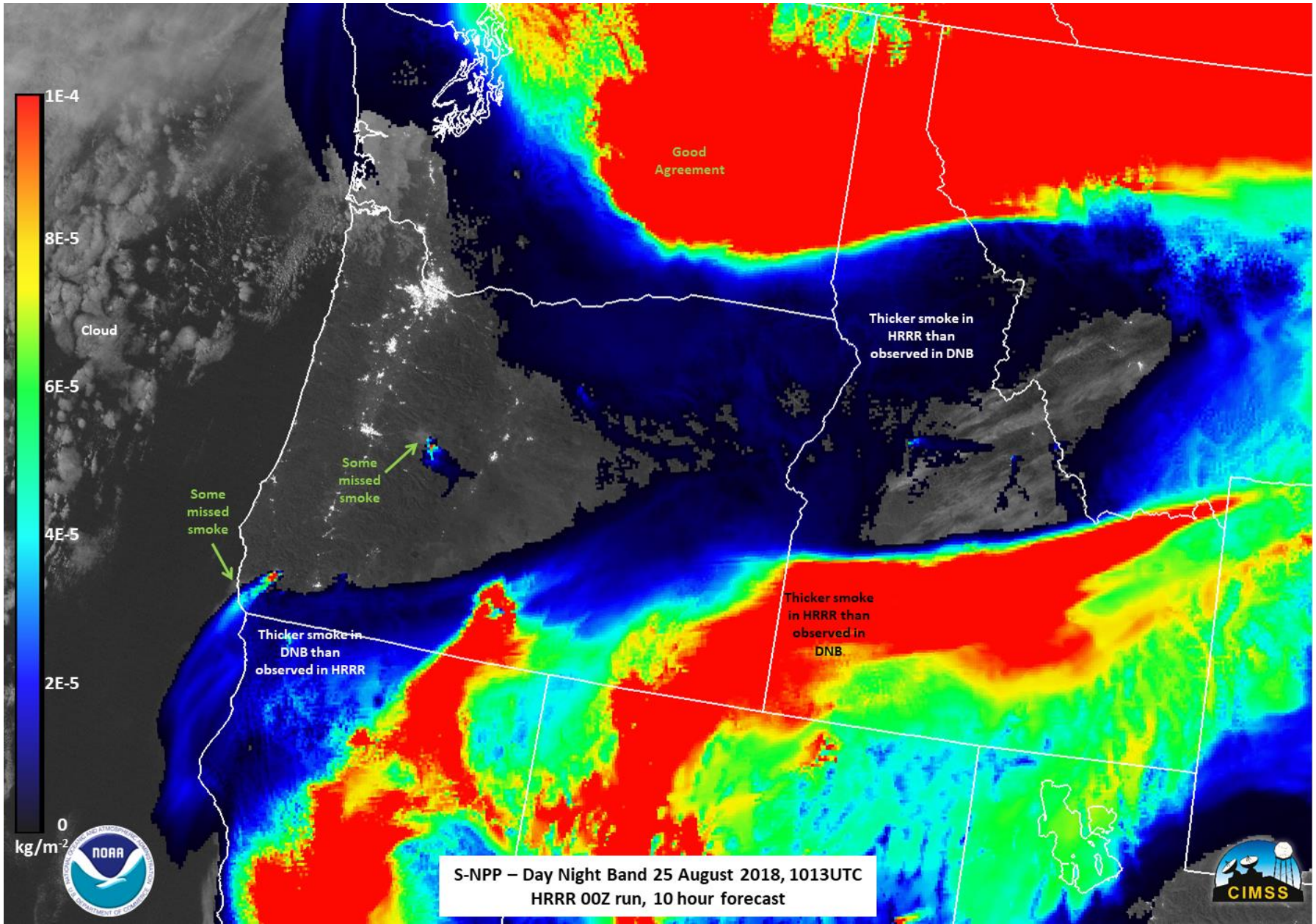
# AOD from HRRR-Smoke



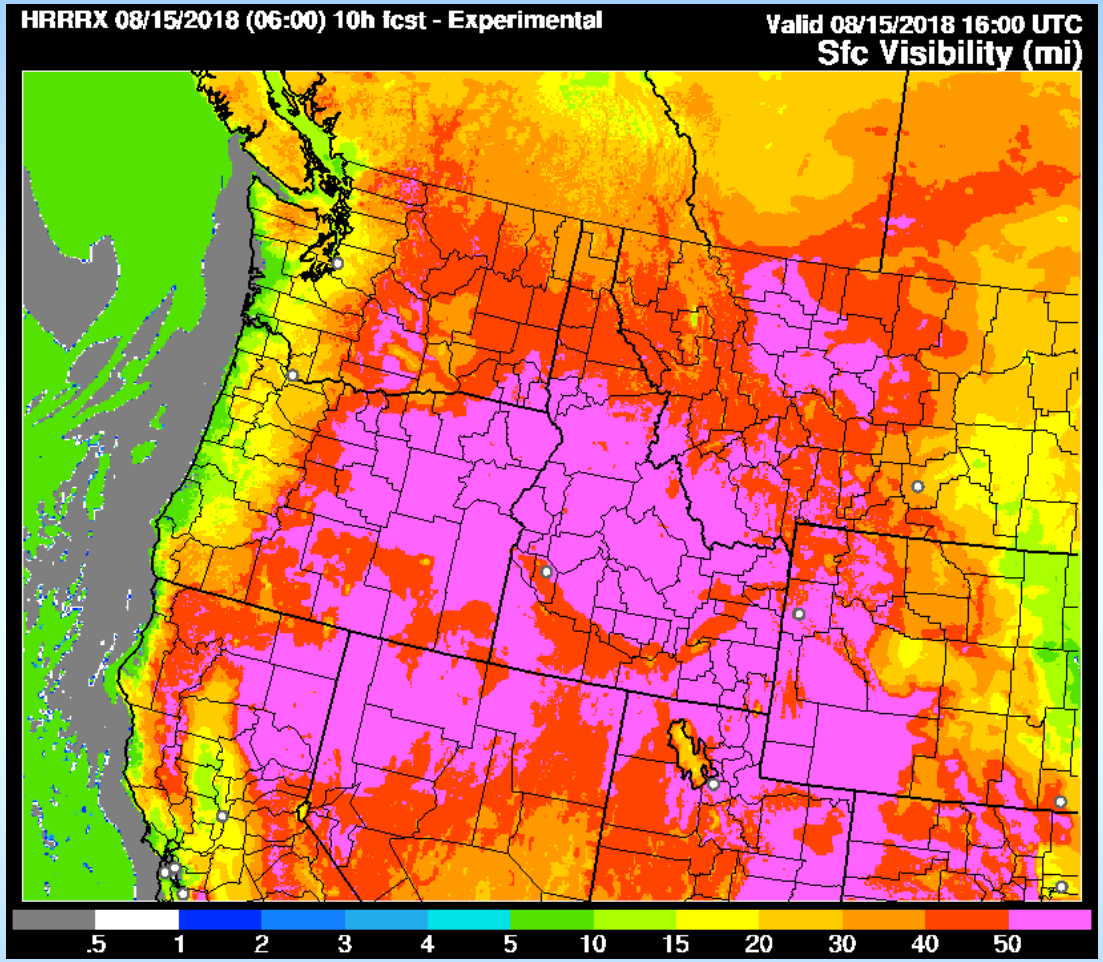




HRRR-Smoke does NOT assimilate the satellite AOD data.

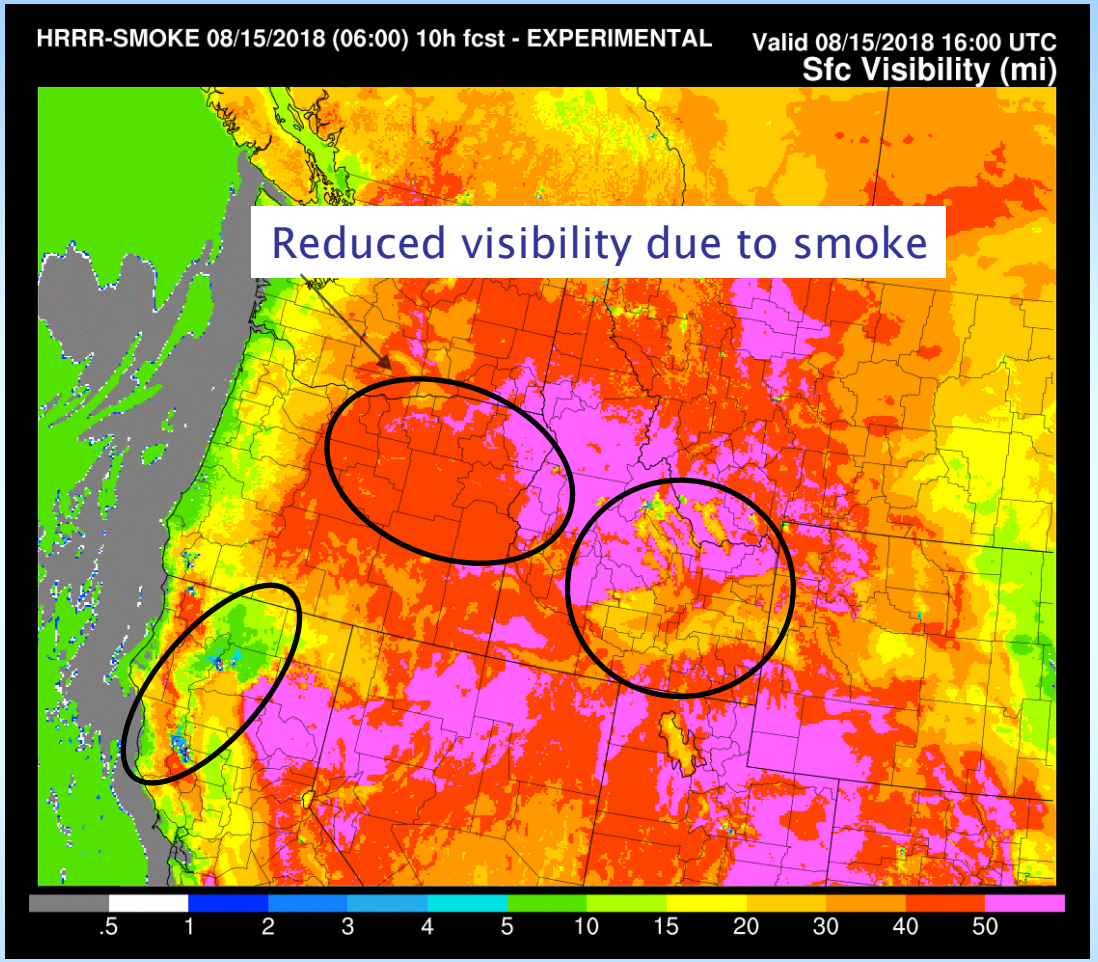
# Qualitative verification of a recent HRRR-Smoke forecast using the S-NPP nighttime images



# Experimental surface visibility forecasts




Experimental NWP system w/o smoke

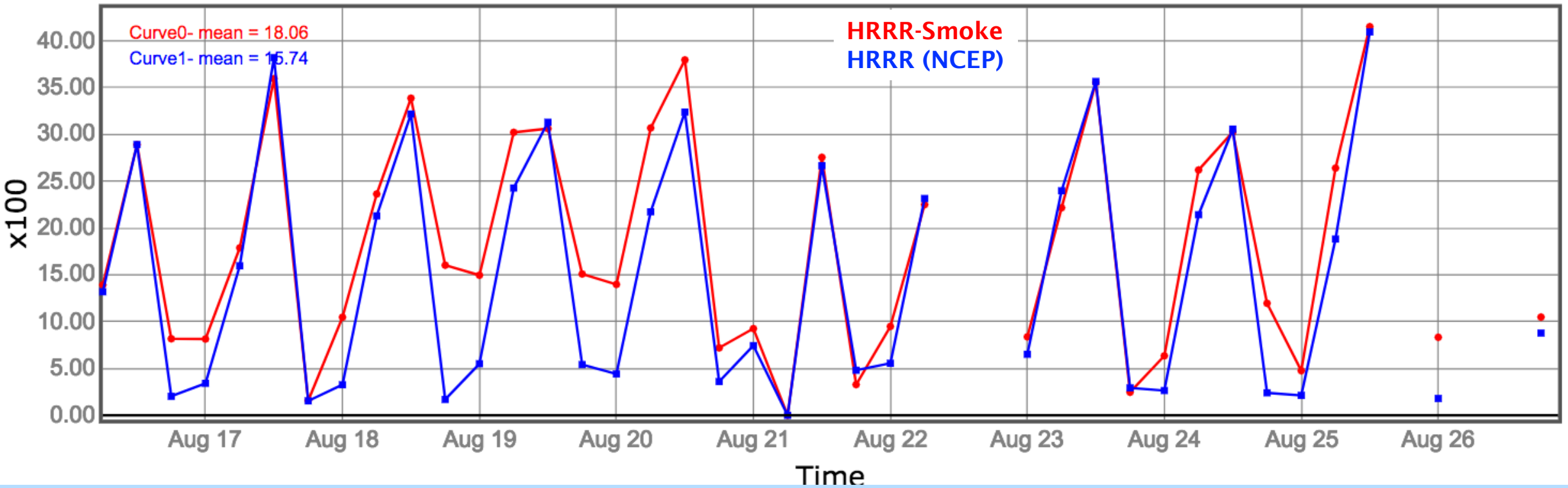



Experimental NWP system with smoke

Visibility is an important forecast product (traffic, aviation…)

# Verification of the surface visibility forecasts over the western US

CSI (Critical Success Index), (visibility < 10 mi), forecast length: 12h, average over the domain



NOAA-20

# Thank you for your attention